NBSIR 74-519

Photometric Tests of Vehicle Glazing Materials

W. A. Hall, E. L. Walters, I. Nimeroff, and C. A. Douglas

Illuminating Engineering Group
Optical Radiation Section
Heat Division
Institute for Basic Standards
National Bureau of Standards

November 1974

Prepared for
Department of Transportation
National Highway Traffic Safety Administration
under
Inter Agency Agreement
No. DOT-HS-185-3-599IA

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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

Preface

Certain commercially available equipment, instruments and materials are identified in this report to specify adequately the experimental procedures used and the materials to which the data obtained apply. In no case should such identification be inferred as an evaluation by the National Bureau of Standards of the suitability of the product for its intended purpose.

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ABSTRACT

Measurements were made on the spectral transmittance of representative vehicle glazing materials and spectral reflectance of representative automobile paints. Colorimetric data were derived from these spectral measurements.

By varying the instrumental parameters of the in-laboratory procedure described in NBS Report No. 10902 for measuring the transmittance of glazing materials, errors in transmittance were obtained and were evaluated. The standard deviation of the transmittance measurements was less than 0.01 except at incidence angles of 70° where it was about 0.02.

1. Introduction

The work described in the report was performed under Inter Agency Agreement No. DOT-HS-185-3-599 IA dated February 15, 1973, between the National Highway Traffic Safety Administration and the National Bureau of Standards. This project is a continuation of the Inter Agency Agreement No. DOT-HS-020-2-312 IA dated March 30, 1972, the results of which were given in NBS Report 10 902, "Photometric Tests of Vehicle Glazing Materials", dated August, 1972. The objectives of this follow-on project are (1) to determine if additional samples of certain types of tinted, IR-absorbing windshields have the very high light transmission characteristics found in the original project and (2) to conduct additional laboratory and in-vehicle tests to provide a broader data base.

The Inter Agency Agreement of 1973 also describes an additional objective, to determine the heat load differences from sunlight between tinted and untinted glazing materials. Interior temperatures under service conditions of a car equipped with a clear windshield were compared to a similar car with a tinted windshield by the Temperature Section of the National Bureau of Standards. The comparison has been reported in NBS Report IR 74-533, "Influence of Windshield Tint on the Temperature in Automobile Passenger Compartments", by W. S. Hurst and M. G. Scroger.

2. Spectral Characteristics of Windshields and Paints

Measurements were made of the spectral transmittances of samples of glazing materials used in the first series of tests, a sample of an electrically heated windshield supplied for the second series of tests and the spectral reflectance of several automobile paints to obtain data for possible use in a theoretical heat-load study. The spectral transmittance of the glazing materials (including the electrically heated Sierracin windshield) are shown in Figures 1 through 6 and the spectral reflectance of the automobile paints are shown in Figures 7 through 11. The chromaticity coordinates for the luminous transmittance and reflectance samples are shown in Table 1.

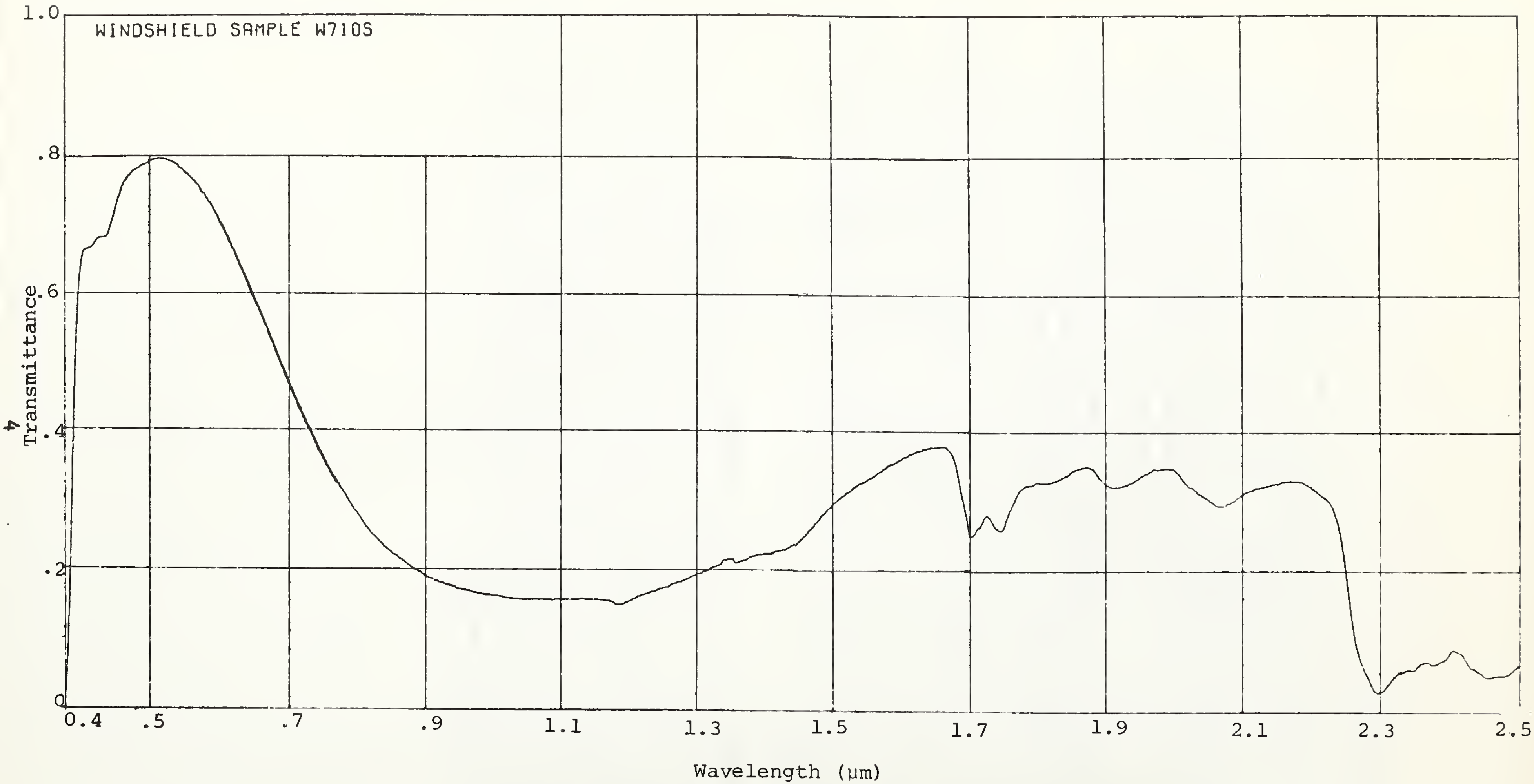

Figure 1. Spectral Transmittance of Automobile Glazing W710S.

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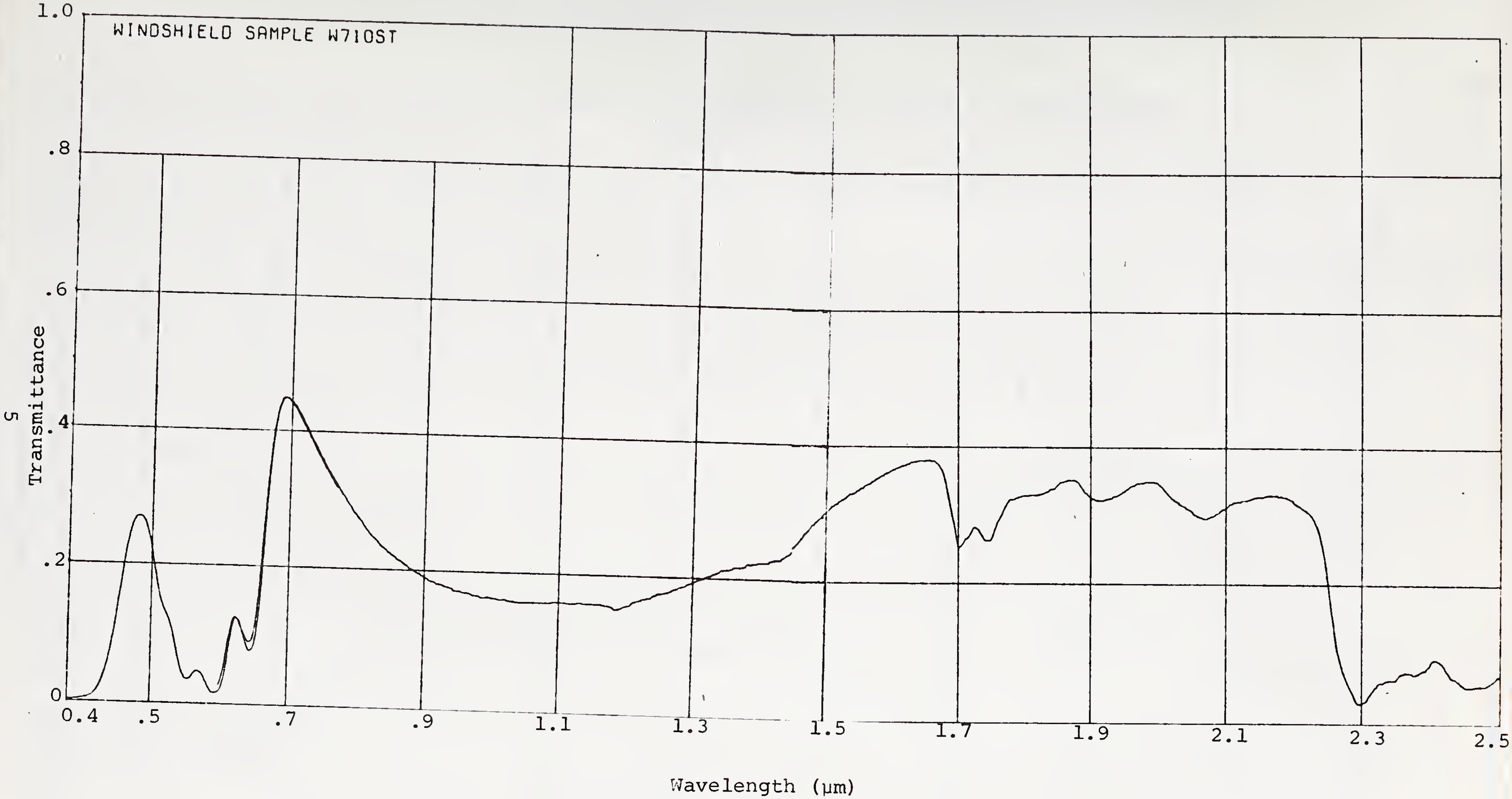

Figure 2. Spectral Transmittance of Automobile Glazing W710ST.

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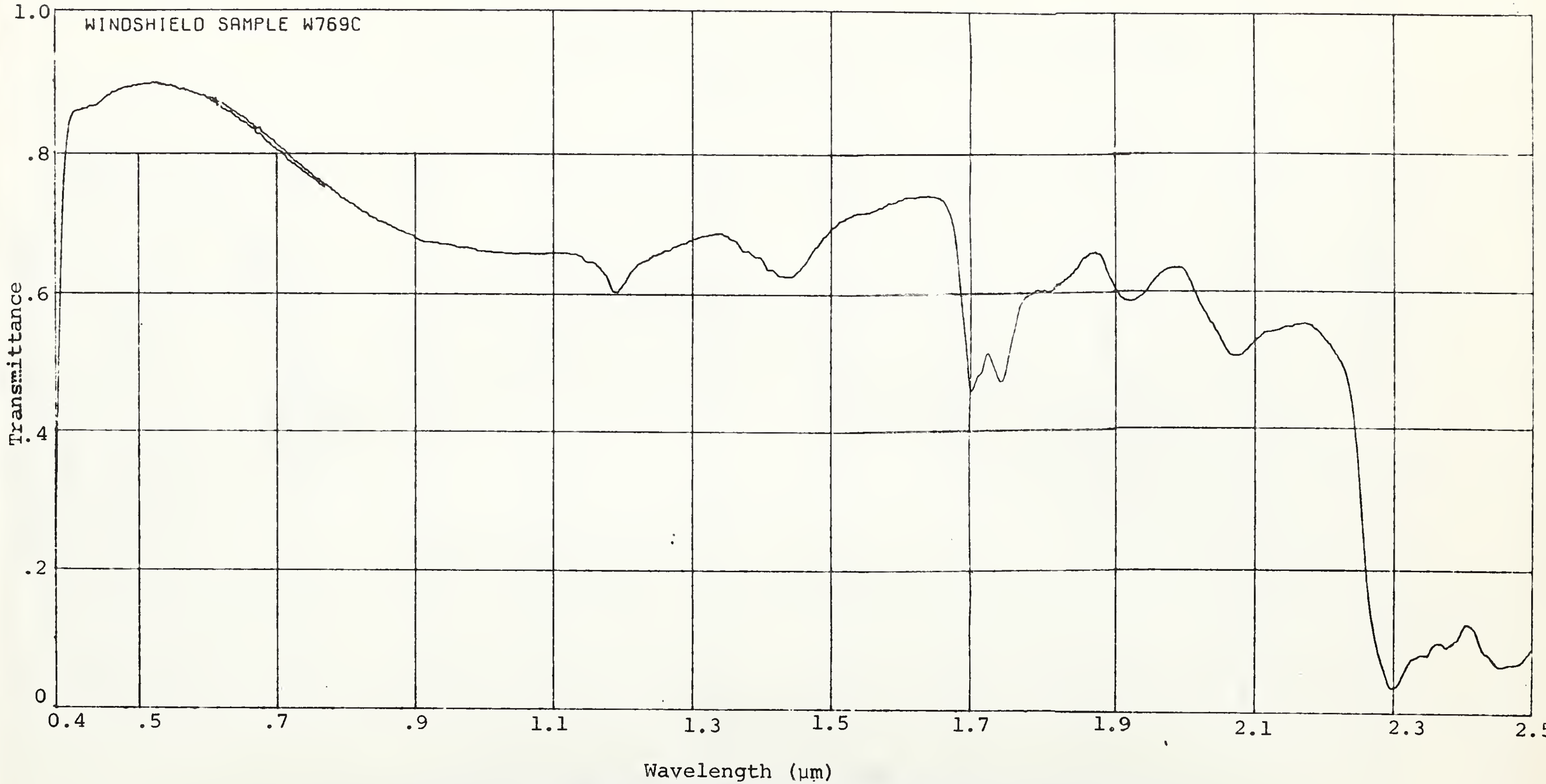

Figure 3. Spectral Transmittance of Automobile Glazing W769C.

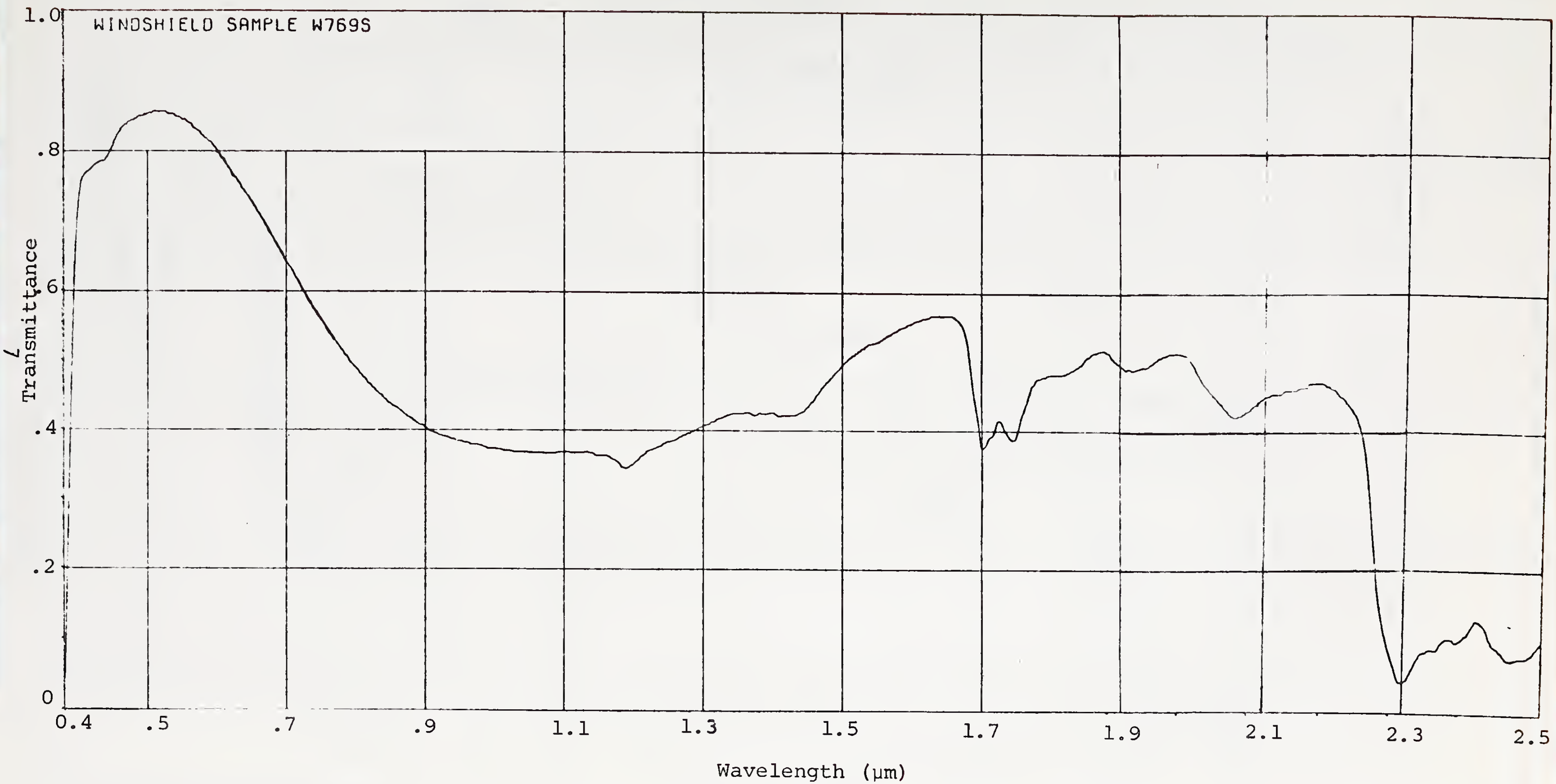

Figure 4. Spectral Transmittance of Automobile Glazing W769S.

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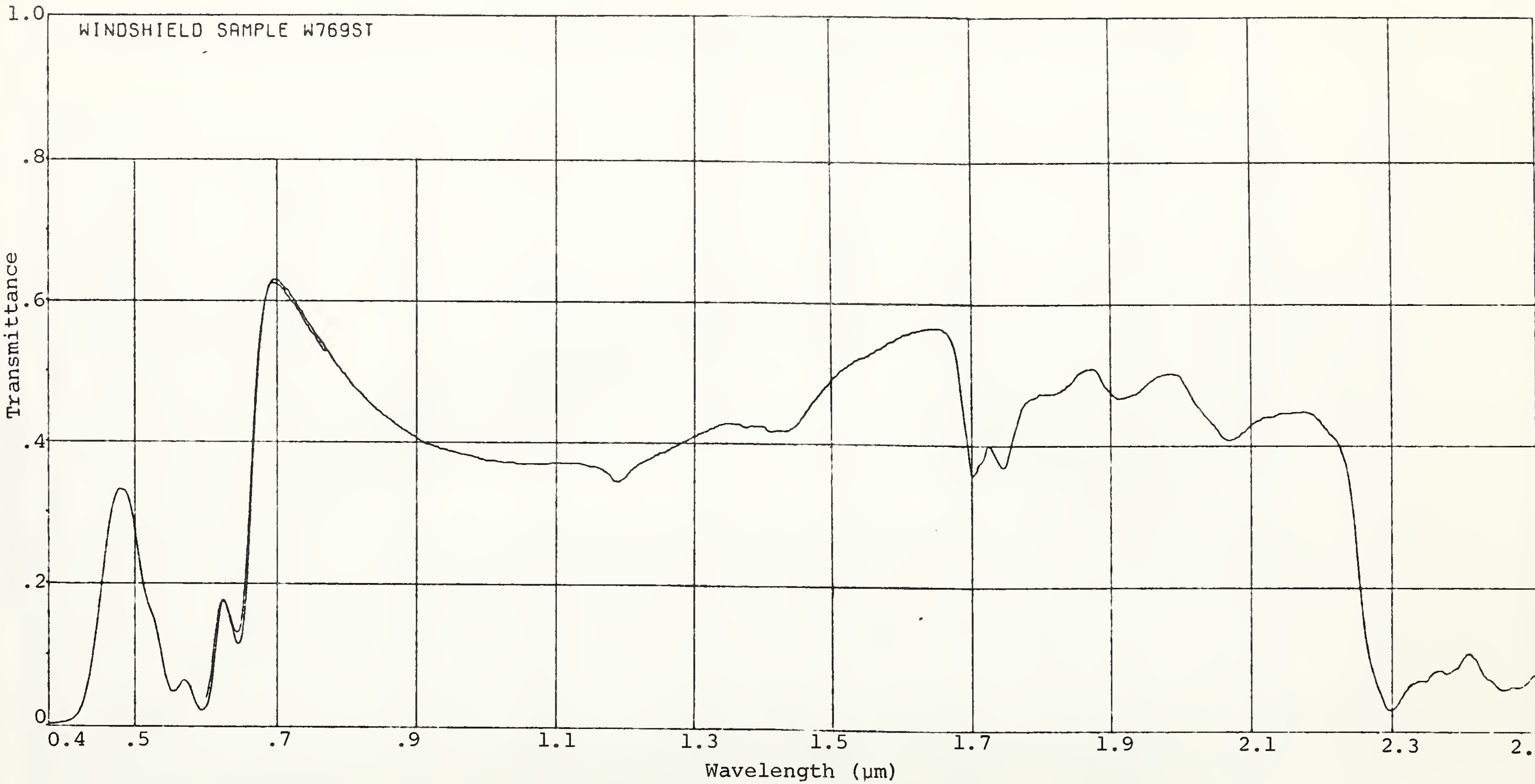

Figure 5. Spectral Transmittance of Automobile Glazing W769ST

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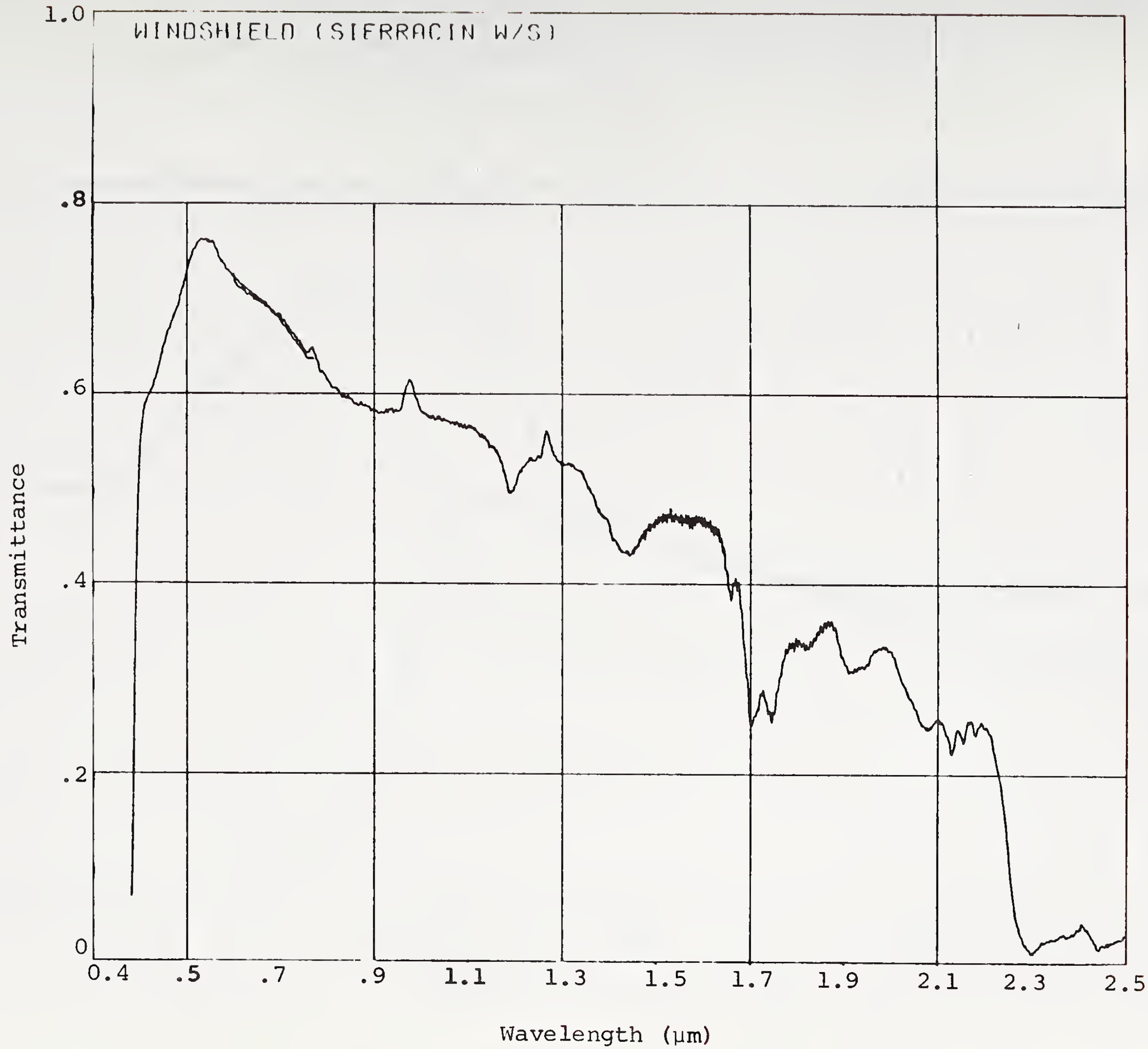

Figure 6. Spectral Transmittance of Automobile Glazing Sierracin W/S

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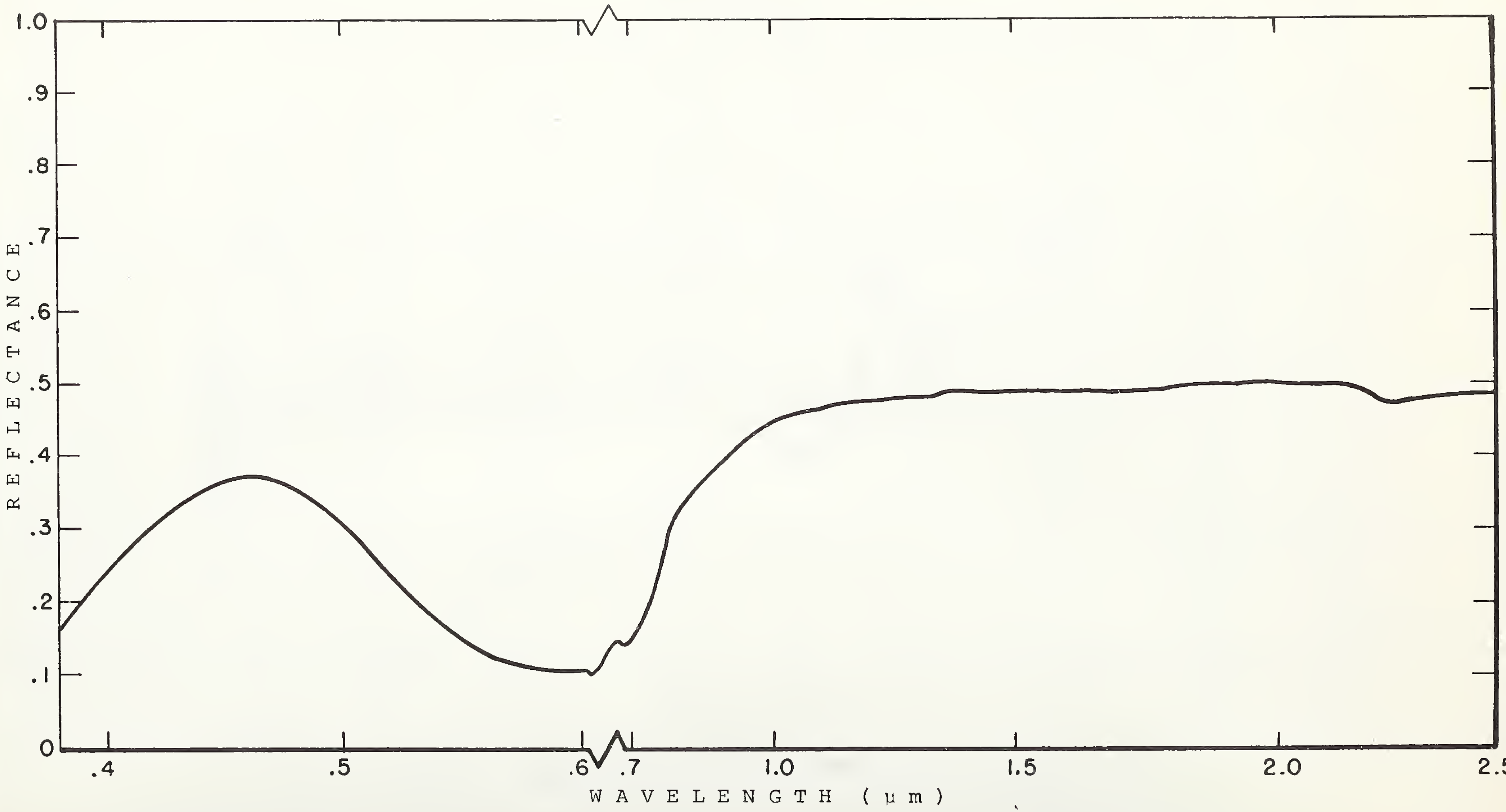

Figure 7. Spectral Reflectance of Automobile Paint
Metallic Blue

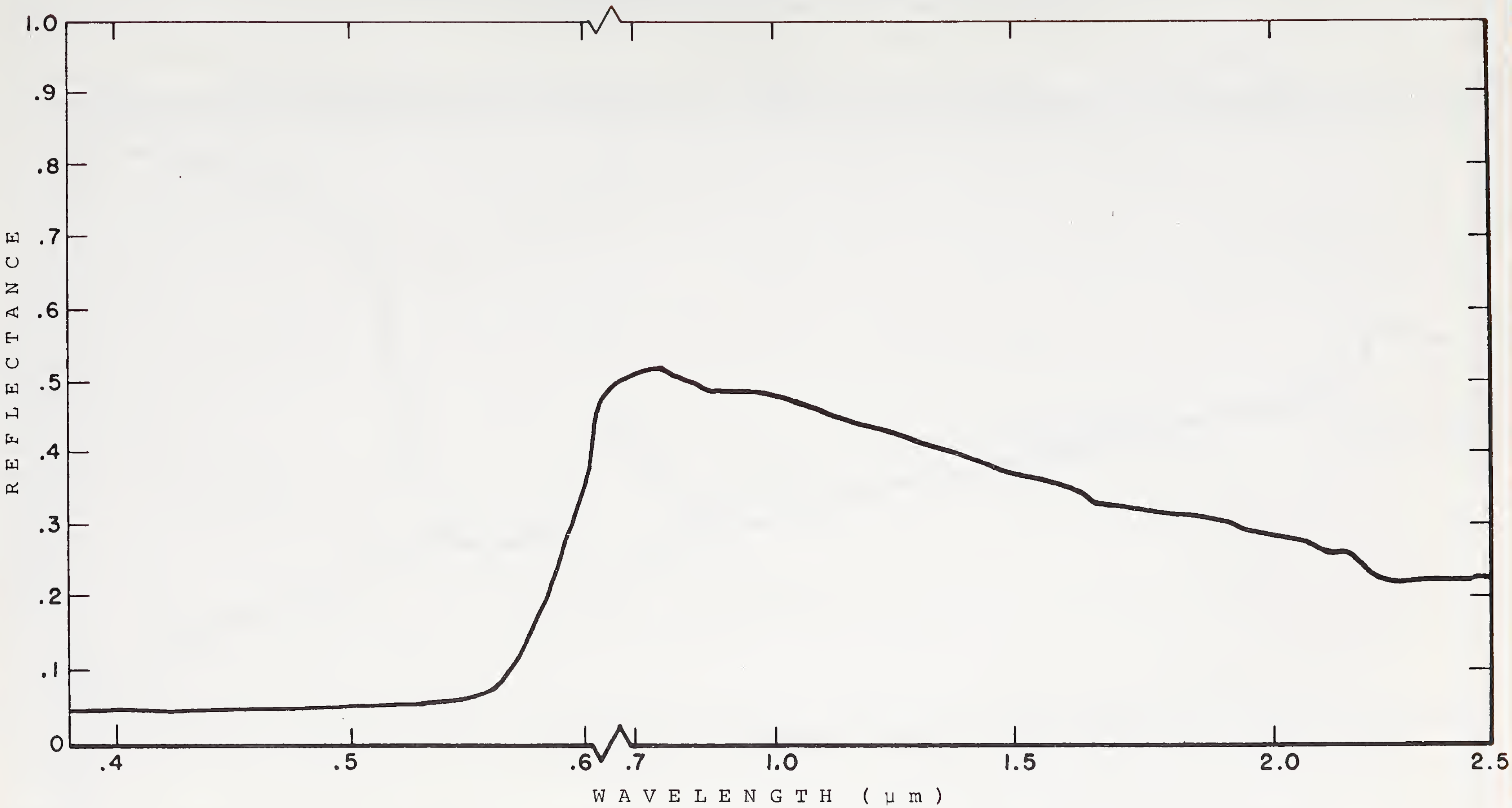

Figure 8. Spectral Reflectance of Automobile Paint
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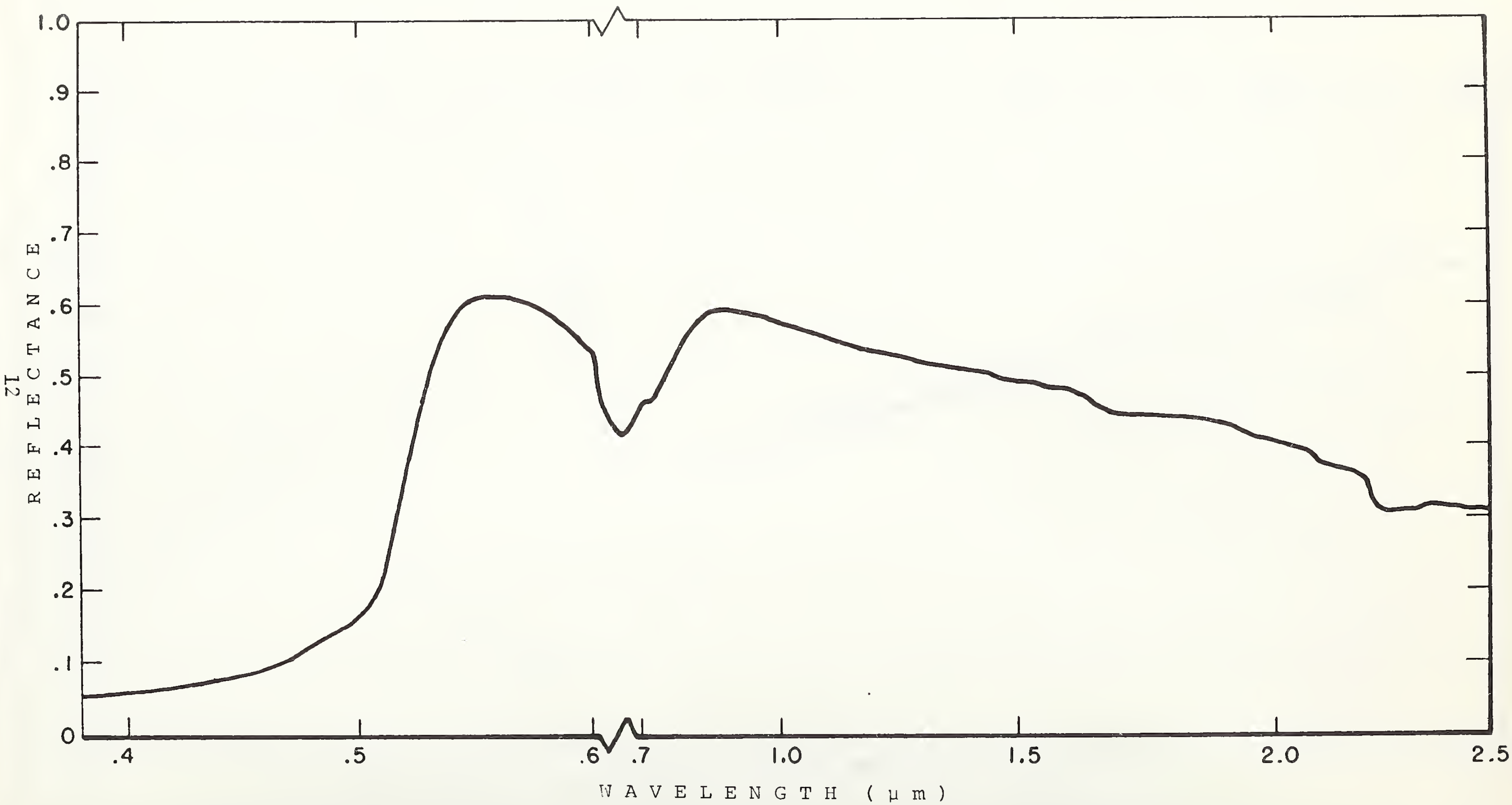

Figure 9. Spectral Reflectance of Automobile Paint
Greenish Yellow

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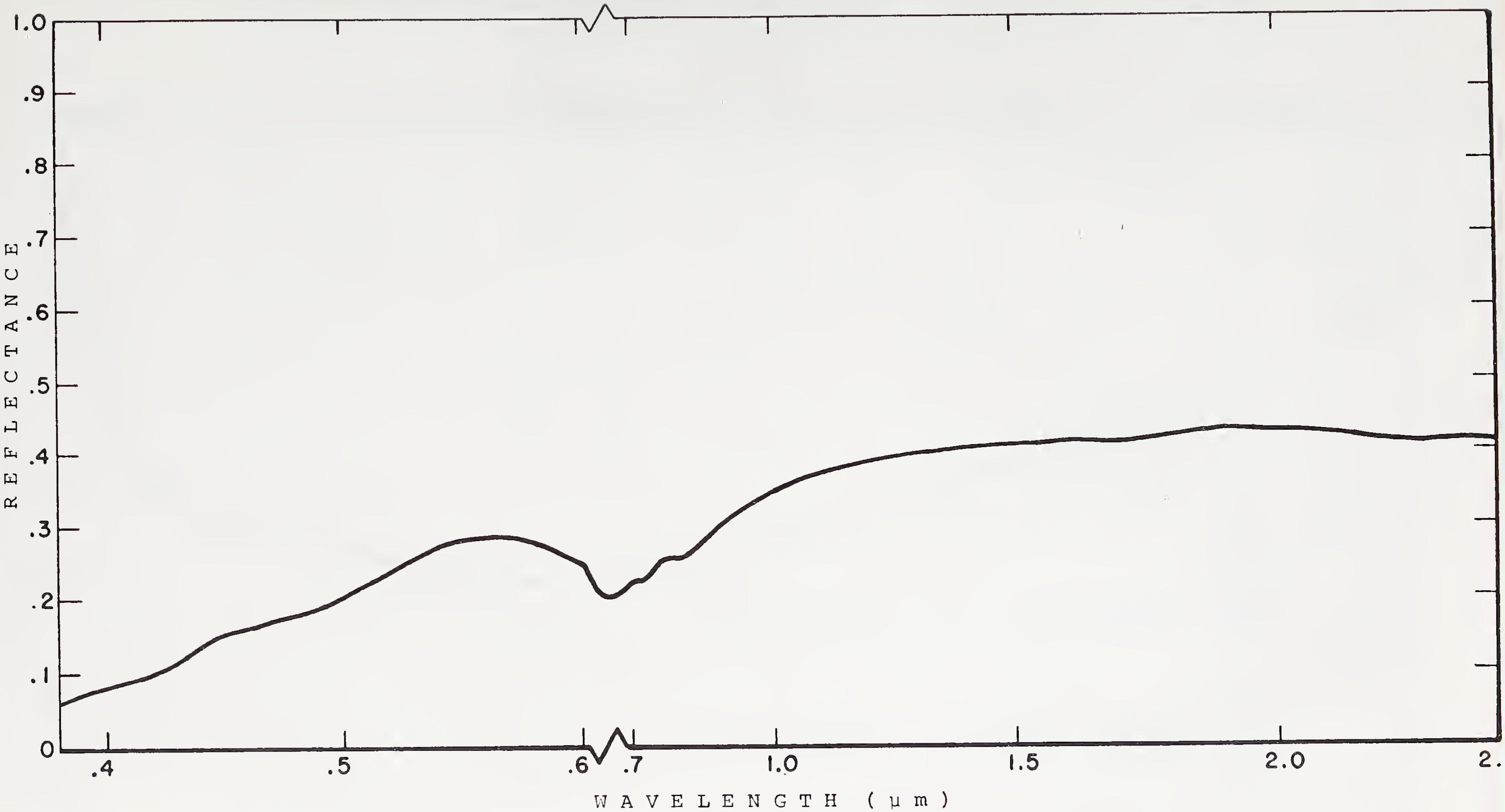

Figure 10. Spectral Reflectance of Automobile Paint
Metallic Green

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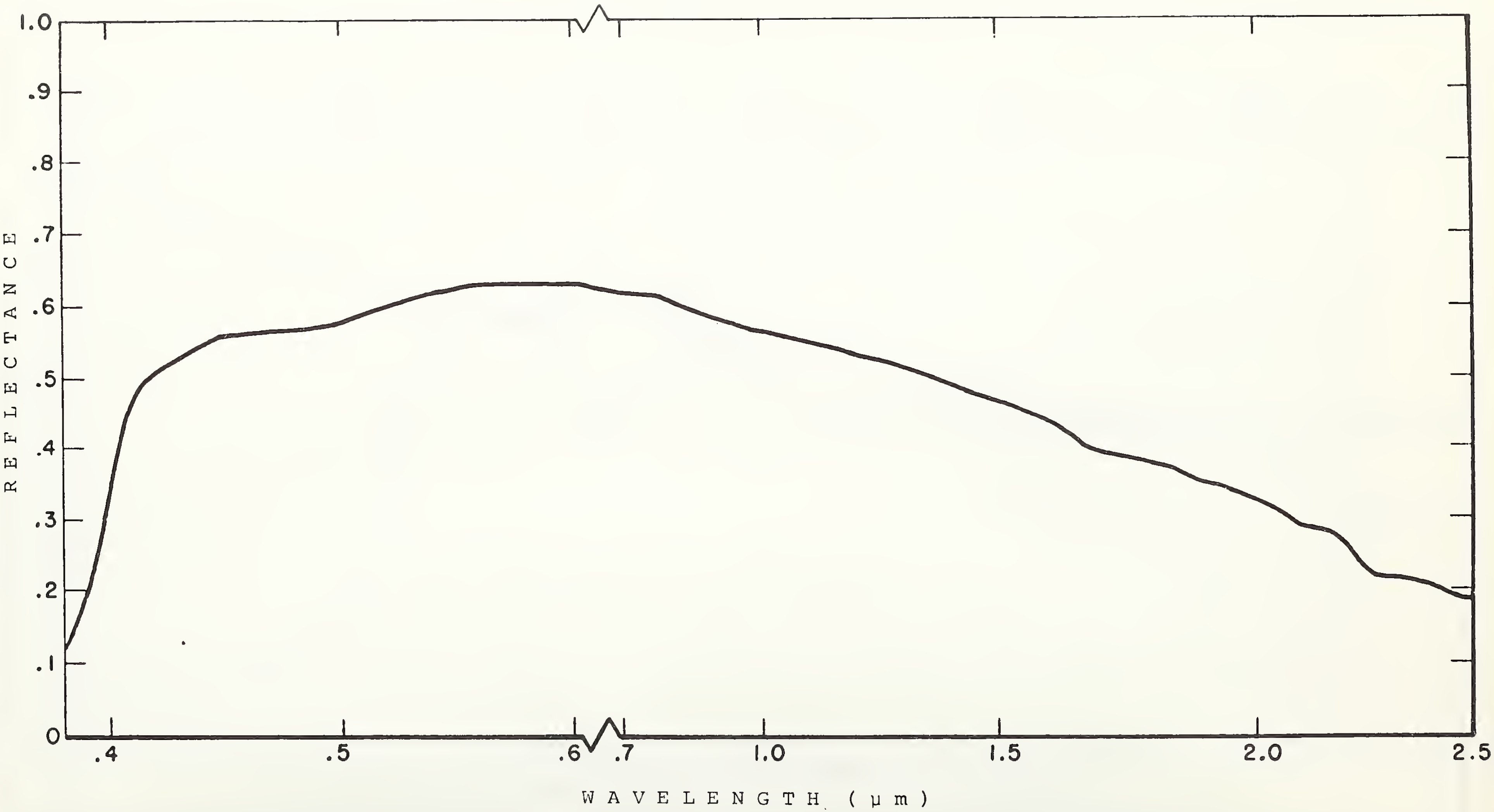

Figure 11. Spectral Reflectance of Automobile Paint
Light Gray

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Table 1. Luminous Transmittance of Automobile Glazing Materials (τ), Luminous Reflectance of Automobile Paints (β) and Chromaticity Coordinates (x, y) for Source A (2856K) Supplied to the Environmental Engineering Section.

Automobile Materials	Sample*		Chromaticity Coordinates x	y	τ(%) (1)	(2)
Glazing	W 710S	(1972)	0.432	0.418	73.5	73.7
	W 710ST	(1972)	.386	.344	7.3	-
	W 769C	(1972)	.445	.410	88.2	88.0
	W 768S	(1972)	.440	.414	82.0	80.4
	W 768ST	(1972)	.402	.345	9.9	-
	Electrically Heated (W/S)	(1974)	.448	.417	73.7	-
					β(%)	
Paint	Metallic Blue		0.347	0.359	14.6	-
	Red		.613	.358	19.9	-
	Greenish Yellow		.495	.468	50.6	-
	Metallic Green		.456	.443	24.8	-
	Light Gray		.454	.414	61.6	-

* Year sample obtained in parenthesis.

(1) From spectrophotometric data.

(2) Reported in NBS Report No. 10902.

3. In-Laboratory Transmittance Measurements

The measurement system for the transmittance measurements was the same as described in NBS Report 10902, Section 2, "Design of the Measuring System". Figure 12 shows the in-laboratory photometric equipment for measuring the transmittance of the glazing materials.

4. Glazing Materials Tested

The vehicle glazing materials measured in the follow-on were purchased from the local distributors of two different manufacturers. A Sierracin windshield (electrically heated glass) was loaned to NBS by the Ford Motor Co., Glass Technology Division, for light transmittance measurements. This sample has been returned to the Ford Motor Company. Table 2 gives the type and number of samples and industry trade number for the glazing materials tested.

5. In-Laboratory Test Procedure

The in-laboratory test procedure was as described in Section 3.1.2, "In-Laboratory Test Procedure", of NBS Report 10902. The following procedures for measurement are extracted from that report.

a. The light source and photometer were turned on and allowed to stabilize for a minimum of 30 minutes. The voltage was monitored with a 0.25% dynamometer voltmeter and regulated to 0.1%.

b. With the photometer aligned on the center of the luminous area of the source, and the test sample removed, the sensitivity of the photometer was adjusted to give a full scale reading (100%) on the X-Y recorder chart. The goniometer table was rotated about a horizontal axis through 90°, giving a 100% trace vs. vertical angle.

c. Prior to the start of the test, the effect of stray light was determined. The stray light reading with the room lights on was found to be less than 0.5% of the full scale reading. Since the tests were made with the room lights off, the effects of stray light were negligible.

d. The test specimen was then mounted on the goniometer, aligned so that the photometric axis was perpendicular to the tangent plane of the windshield at the point of intersection with the specimen, and then cleaned.

e. The goniometer was then rotated about its horizontal axis through 90°, giving the measurement of transmittance as a function of the angle between the normal to the specimen and the photometric axis. The transmittance was measured at three additional points on each test specimen normal (0°) to the specimen, to determine the uniformity of the transmittance.

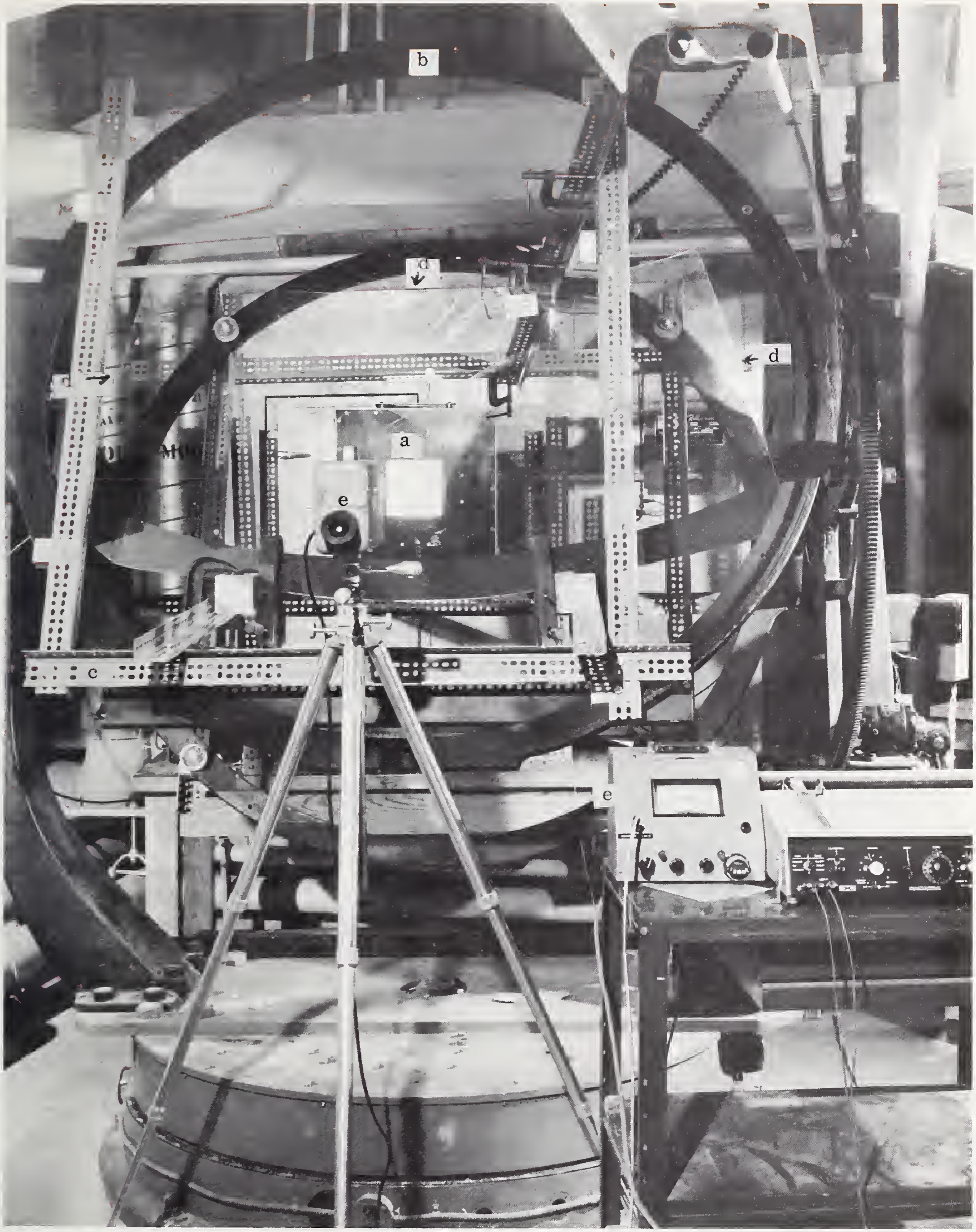

FIGURE 12. GENERAL VIEW OF IN-LABORATORY PHOTOMETRIC EQUIPMENT
a. Light Source, b. Goniometer, c. Sample Frame
d. Sample Windshield, e. Photometer Receiver, Photometric Indicator and Recorder

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Table 2. Description and Number of Samples for In-Laboratory Measurements

DESCRIPTION	Number Tested	Industry Trade No.
Windshield, tinted	5	W769
Windshield, tinted	5	W799
Back window, tinted	2	B4625
Back window, clear	2	B4625
Side window, front, tinted	2	D4620 D4621
Side window, front, clear	2	D4620 D4621
Windshield, electrically heated	1	-

6. In-Laboratory Results

6.1 Variation of Transmittance with Incidence Angle

The results of the transmittance measurements of one sample from each group as well as for the electrically heated windshield are shown in Figures 13-19.

The complete tabulation of the results of the measurements is given in Table 3.

6.2 Precision of Measurements

In addition to the measurements of transmittance shown in Table 3, two of the windshield samples, W-799-3E and the Electrically Heated, were measured several times to determine the precision (repeatability) of the measurement. In addition, different parameters of the measurement system were varied to determine the sensitivity of the measurement system. The changes were (1) the source voltage was reduced from 116.0 V to 60.0 V, (2) a 3/8 inch diaphram was installed on the photometer lens, (3) the distance from the source to the photometer was varied from approximately one-half the normal distance (approximately 10 ft.) to twice the distance, (4) the photometer was aligned at an angle of about 1° from the normal (perpendicular) to the source instead of normal.

The results of repeated transmittance measurements and measurements with variations of the parameters are given in Tables 4 and 5. The measurements at various distances and at a 1° deviation from normal incidence on windshield W799-3E were within the spreads of the measurements given in the Table 4.

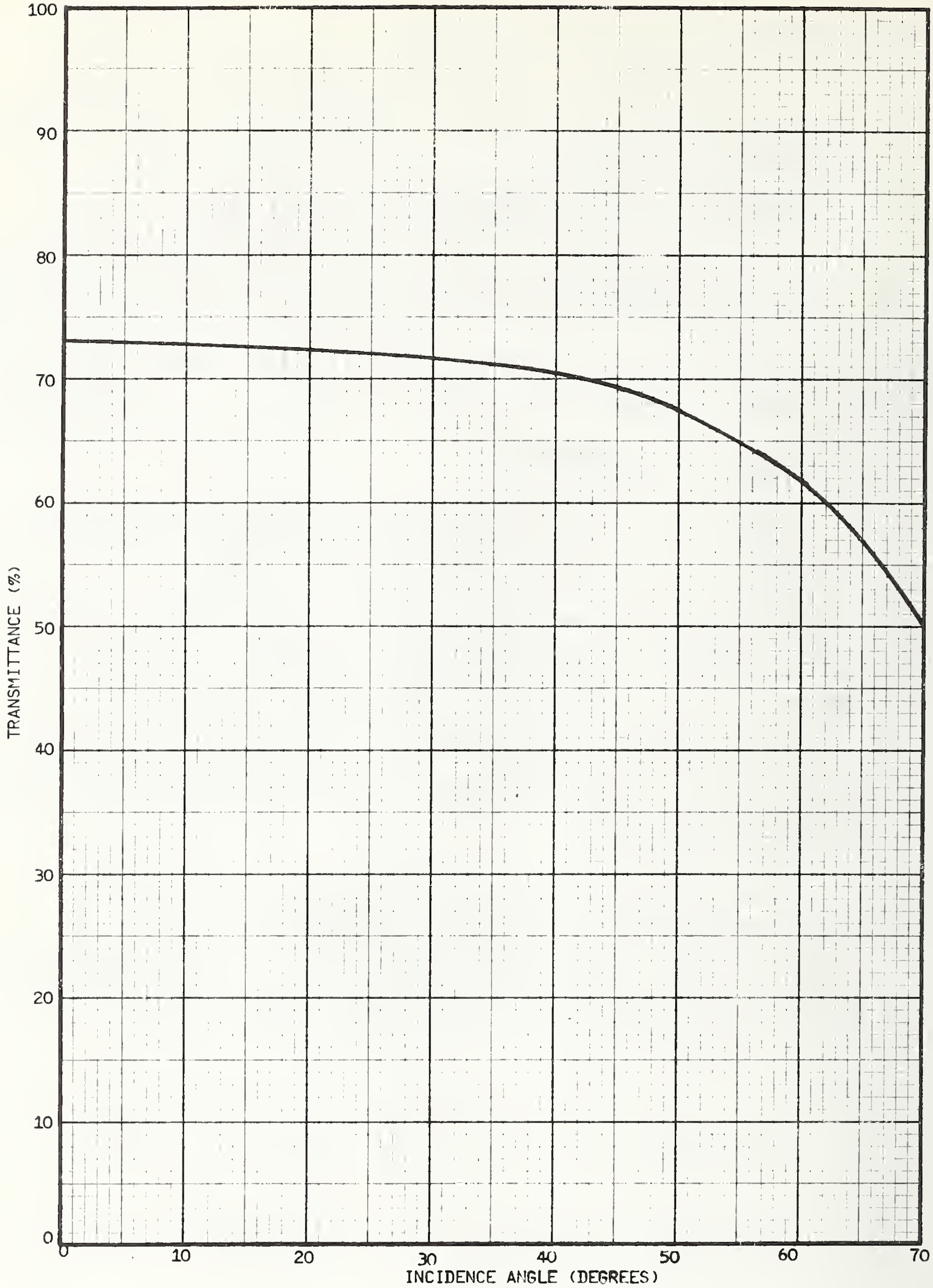

FIGURE 13. VARIATION OF TRANSMITTANCE WITH INCIDENCE ANGLE OF GLAZING MATERIAL: W769, SHADED, XU 1

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FIGURE 14. VARIATION OF TRANSMITTANCE WITH INCIDENCE ANGLE OF GLAZING MATERIALS: W799, SHADED, XU 3A

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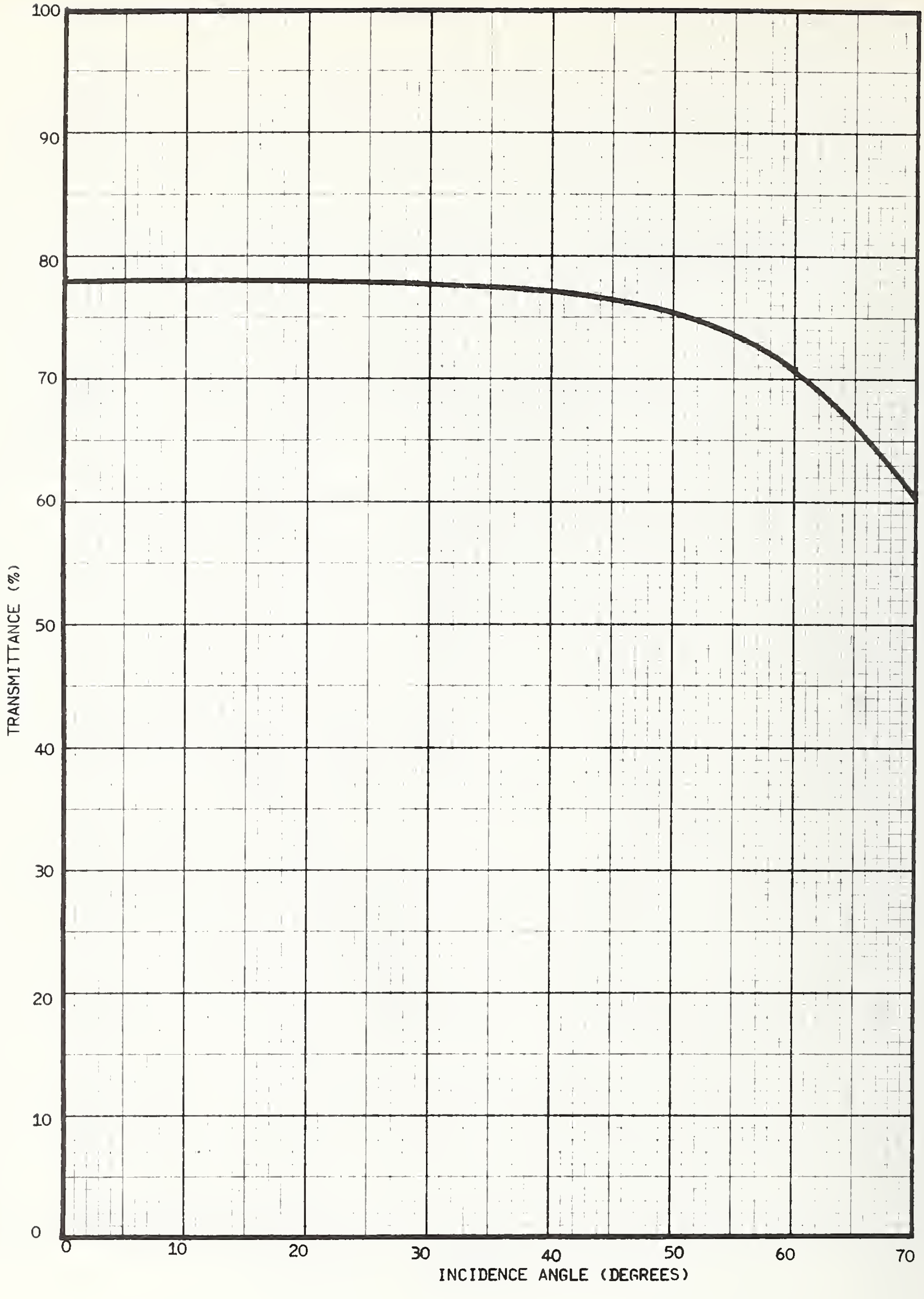

FIGURE 15. VARIATION OF TRANSMITTANCE WITH INCIDENCE ANGLE OF GLAZING MATERIAL: ELECTRICALLY HEATED, 3D

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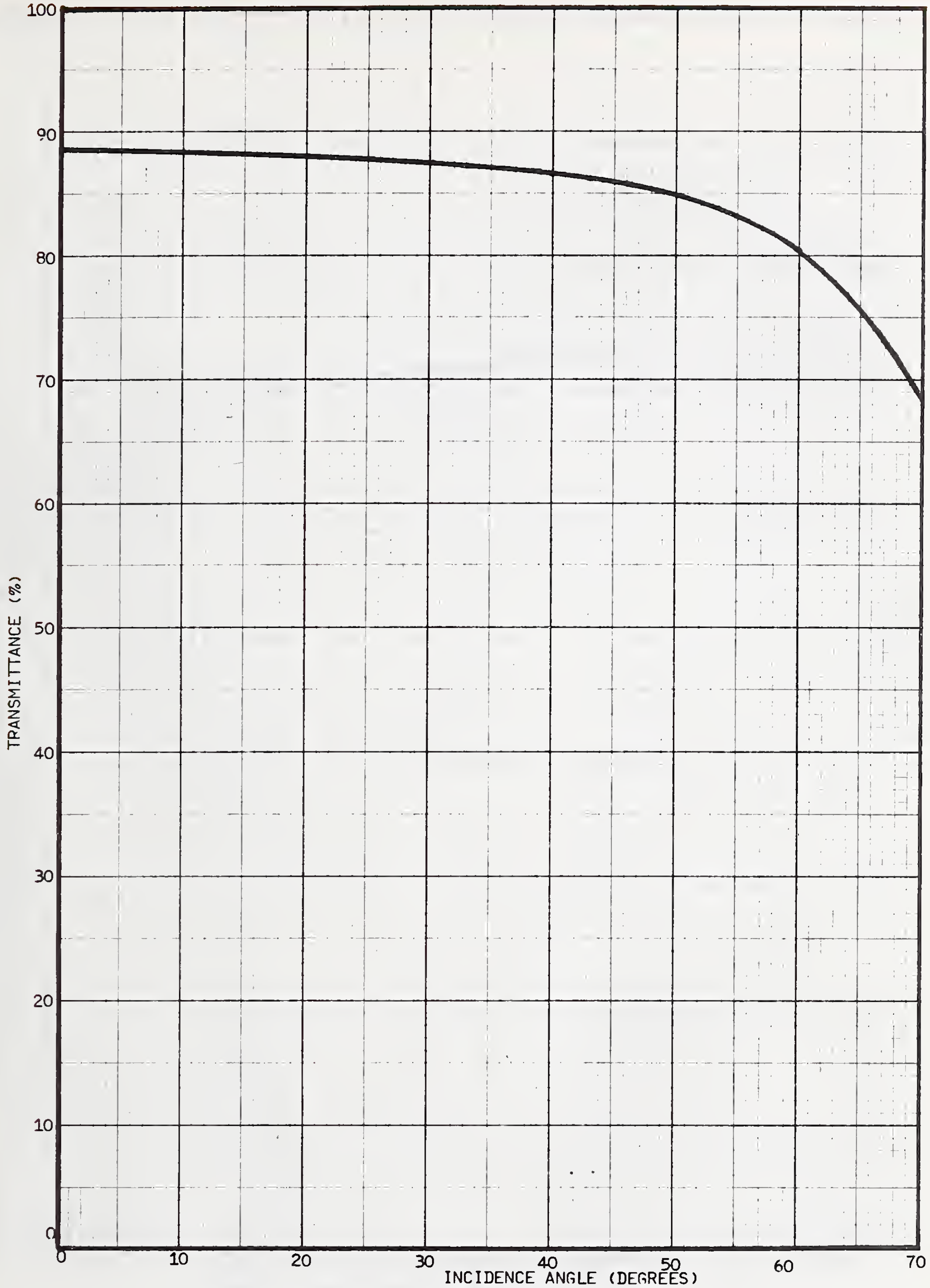

FIGURE 16. VARIATION OF TRANSMITTANCE WITH INCIDENCE ANGLE OF GLAZING MATERIAL: B4625, CLEAR, AS2-AT

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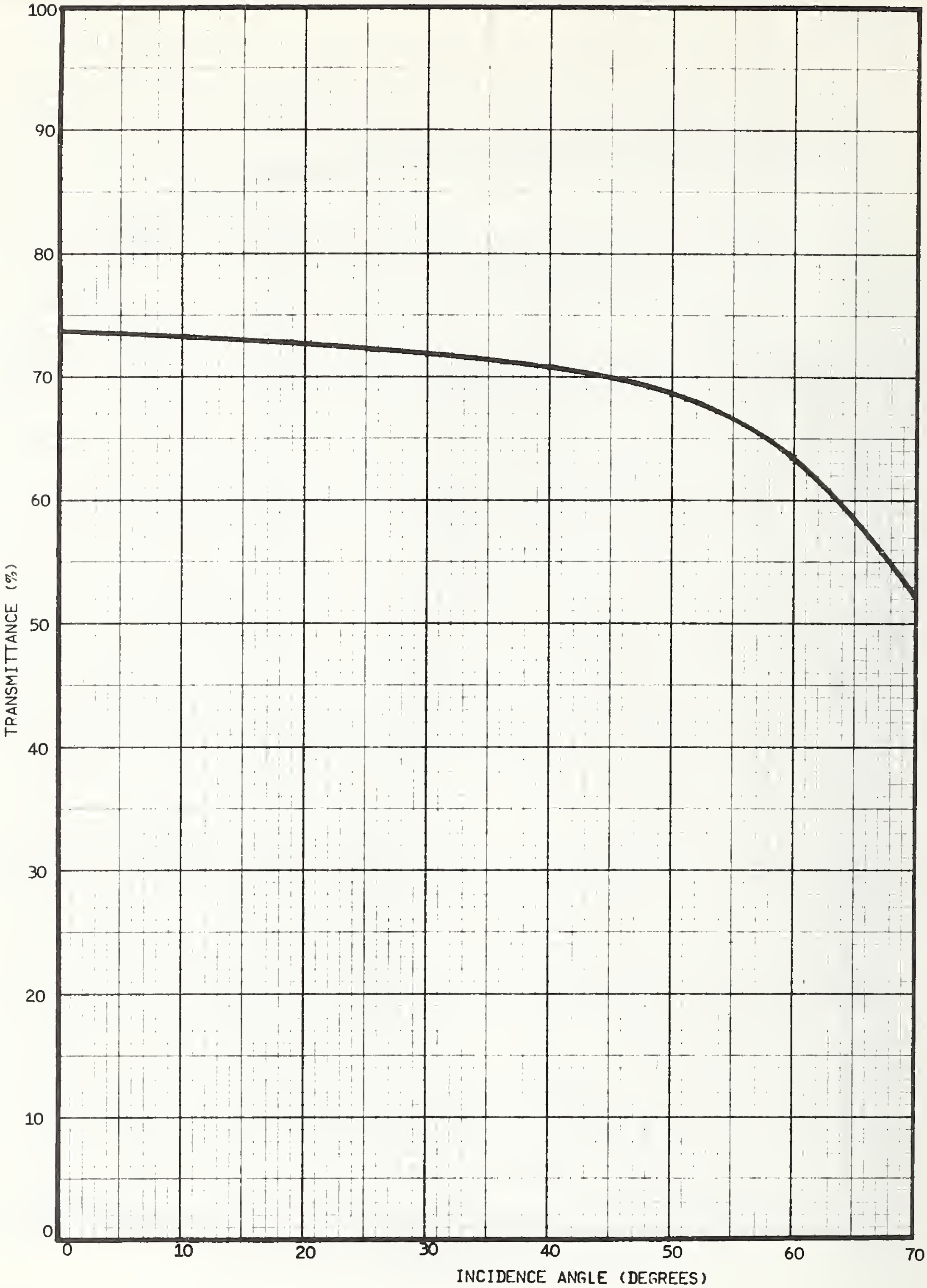

FIGURE 17. VARIATION OF TRANSMITTANCE WITH INCIDENCE ANGLE OF GLAZING MATERIAL: B4625, TINTED, AS2-CY

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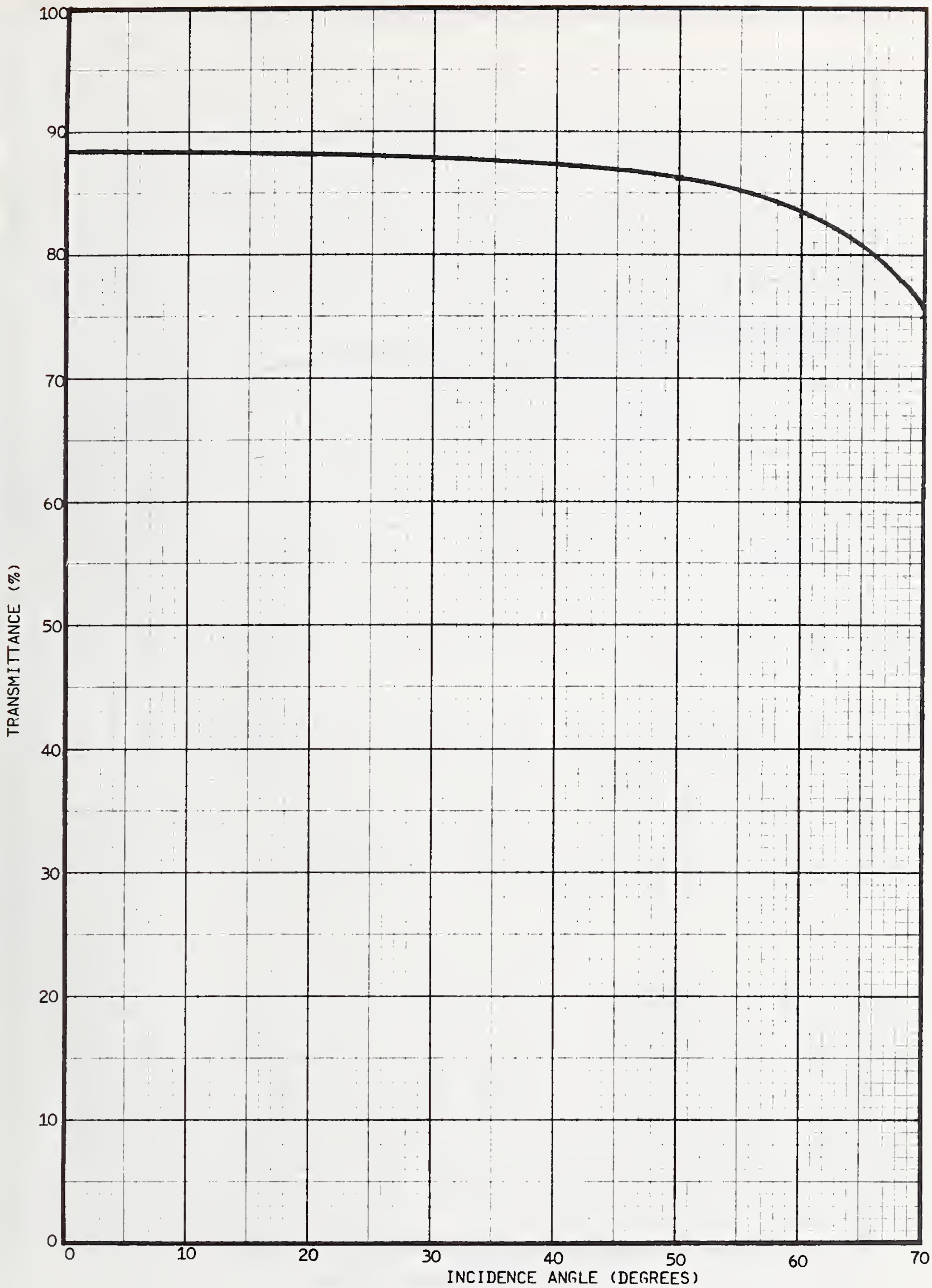

FIGURE 18. VARIATION OF TRANSMITTANCE WITH INCIDENCE ANGLE OF GLAZING MATERIAL: D 4620, CLEAR, AS2-UT

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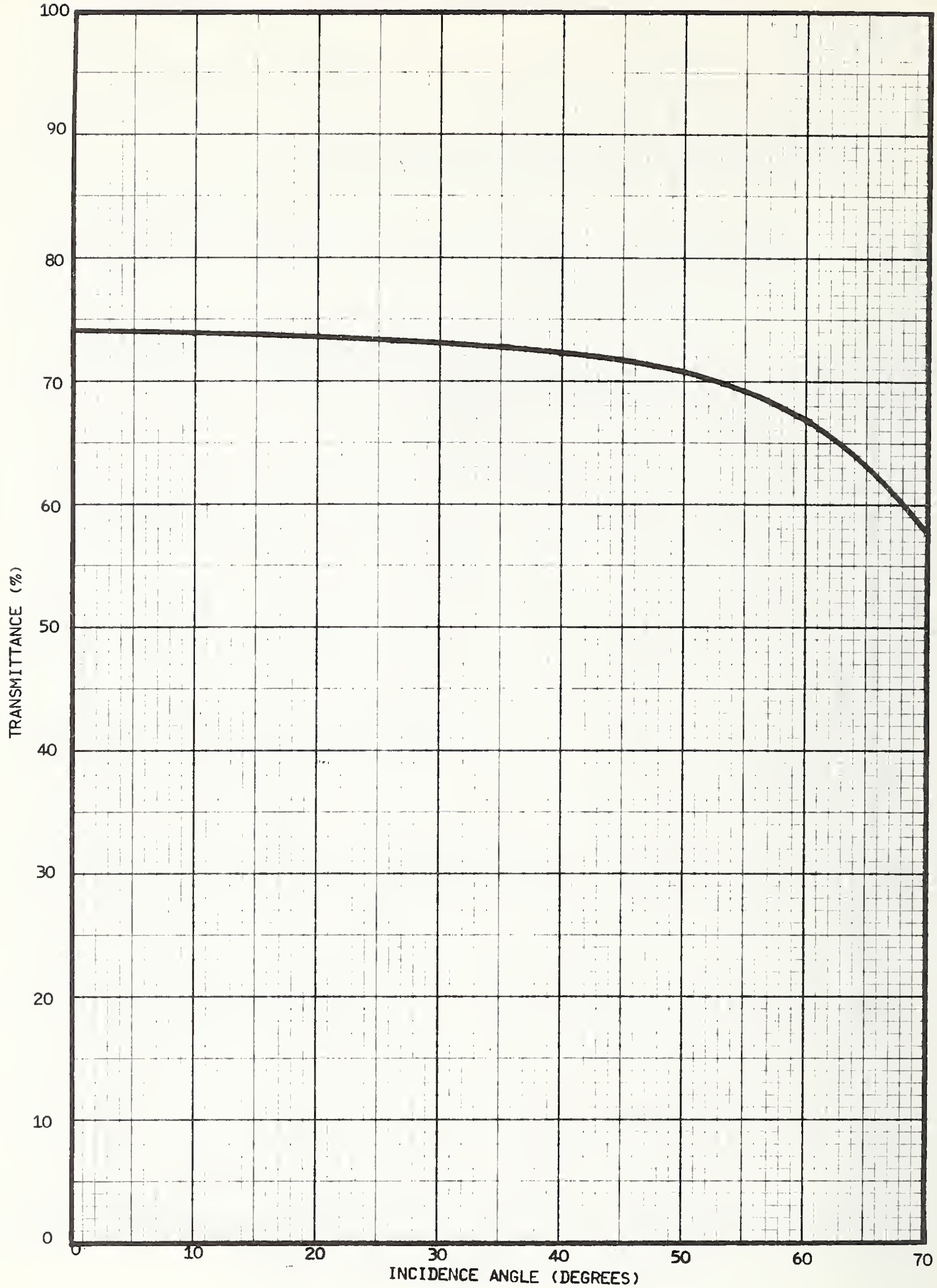

FIGURE 19. VARIATION OF TRANSMITTANCE WITH INCIDENCE ANGLE OF GLAZING MATERIAL: D4621, TINTED, AS2-TY

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Table 3. Variation of Transmittance with Angle

			ANGLE (degrees)							
Location	DOT No.	Industry Trade No.	0	10	20	30	40	50	60	70
Windshield	15-M32	W769 Shaded XU 1	73.0	73.0	72.7	71.4	70.2	67.4	62.0	50.5
		W769 Shaded XU 2	72.8	72.8	72.0	71.3	70.1	67.7	63.3	52.4
		W769 Shaded XU 3	72.0	71.9	71.9	71.0	70.1	68.0	63.1	52.4
		W769 Shaded XU 4	73.1	72.7	72.2	71.5	70.2	67.9	63.2	52.4
		W769 Shaded XU 5	72.4	72.2	72.1	71.1	70.0	67.5	62.9	51.8
	75-FMM91	W799 Shaded XU 3A	80.7	80.7	80.5	79.7	78.7	76.7	72.1	61.0
		W799 Shaded XU 3C	80.9	80.9	80.7	79.8	79.2	77.6	72.5	61.1
		W799 Shaded XU 3D	80.9	80.9	80.5	79.8	79.1	77.0	72.3	60.8
		W799 Shaded XU 3E	80.6	80.6	80.4	80.1	79.4	77.8	73.2	61.2
		W799 Shaded XU 2M	80.4	80.4	80.4	80.0	79.4	77.3	72.3	60.4
	75-FMM81	(Electrically Heated) 3D	78.2	78.2	78.2	77.6	77.1	75.2	71.0	60.7
Back Window	15-M74	B4625 T, AS2-CY	73.5	73.3	72.9	71.9	70.8	68.5	63.6	52.3
		B4625 T, AS2-NU	73.5	73.2	72.9	72.0	70.8	68.8	64.1	53.6
	15-M71	B4625 C, AS2-AT	88.5	88.5	88.1	87.5	86.7	85.2	80.4	68.8
		B4625 C, AS2-YT	88.1	88.1	88.1	87.3	86.7	85.2	80.7	69.1
Side Window	15-M71	D4620, AS2-UT	88.4	88.4	88.2	87.8	87.4	86.2	83.2	75.0
		D4621, AS2-NV	88.0	88.0	88.0	87.9	87.2	86.2	83.0	74.0
	15-M74	D4620, AS2-UN	74.1	73.9	73.5	73.1	72.4	70.8	67.6	60.1
		D4621, AS2-TY	74.0	74.0	73.9	73.0	72.1	70.5	66.8	57.8

Table 4. Variation of Transmittance (%) of Automobile Glazing, W799-3E, with Variation of Parameters

Angle (deg)	6/28*	11/29	12/3	12/4	12/4 (Source at 60.0 V)	12/14	12/14 (3/8" diaphram)	Ave.	Range, R Low - High - R	σ**
0	80.6	81.5	81.1	81.5	81.3	81.7	81.5	81.3	80.6 - 81.7 - 1.1	0.37
10	80.6	81.5	81.1	81.5	81.3	81.7	81.5	81.3	80.6 - 81.7 - 1.1	.37
20	80.4	81.4	81.1	81.3	81.0	81.7	81.5	81.2	80.4 - 81.7 - 1.3	.42
30	80.1	81.0	80.5	81.1	80.3	81.1	81.0	80.7	80.1 - 81.1 - 1.0	.42
40	79.4	79.9	79.8	80.2	79.7	80.5	80.5	80.0	79.4 - 80.5 - 1.1	.42
50	77.8	78.1	77.9	78.2	78.1	79.0	78.9	78.3	77.8 - 79.0 - 1.2	.47
60	73.2	73.5	74.3	74.2	74.0	75.5	75.4	74.3	73.2 - 75.5 - 2.3	.88
70	61.2	63.5	64.9	64.3	64.6	67.6	67.2	64.8	61.2 - 67.6 - 6.4	2.18

* Dates on which the measurements were made.

** Of a single measurement.

Table 5. Variation of Transmittance (%) of Electrically Heated (Sierracin) Glazing with Variation of Parameters

Angle (deg)	7/12*	11/29	12/3	12/4	12/14	12/14 (Source at 60.0 V)	Ave.	Range, R Low - High - R	σ**
0	78.2	76.6	76.6	76.4	77.2	77.3	77.0	76.4 - 78.2 - 1.8	0.67
10	78.2	76.6	76.6	76.4	77.2	77.3	77.0	76.4 - 78.2 - 1.8	.67
20	78.2	76.3	76.6	76.3	77.2	77.4	77.0	76.3 - 78.2 - 1.9	.74
30	77.6	75.8	76.4	76.0	76.9	76.8	76.6	75.8 - 77.6 - 1.8	.66
40	77.1	75.2	75.5	75.3	76.2	76.4	76.0	75.2 - 77.1 - 1.9	.74
50	75.2	73.7	74.0	74.1	74.9	75.0	74.5	73.7 - 75.2 - 1.5	.62
60	71.0	70.5	71.2	70.9	72.0	71.8	71.2	70.5 - 72.0 - 1.5	.57
70	60.7	62.6	63.9	63.7	64.9	64.4	63.4	60.7 - 64.9 - 4.2	1.52

* Dates on which the measurements were made.

** Of a single measurement.

7. Discussion

The slight rise in transmission of the glazing materials, which was shown in the data in NBS Report 10902, between 0° and 20°, was investigated during this follow-on project. It was found that this rise was caused not by the glazing materials, but by a slight anomaly in the photometer used for the measurement. This photometer error was eliminated during the measurements performed for this project.

The loss of precision at the 70° incidence angle results from small deviations in initial alignment which have a greater effect at large incidence angles where the change of transmittance with angle is large. In the repeated measurements of transmittance, the windshields were aligned using the care that was expected of a careful tester in the field. Sophisticated techniques and equipment, such as lasers, were not used. The results, therefore, are indicative of the precision expected from field measurements.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Measurements were made on the spectral transmittance of representative vehicle glazing materials and spectral reflectance of representative automobile paints. Colorimetric data were derived from these spectral measurements.

By varying the instrumental parameters of the in-laboratory procedure described in NBS Report No. 10902 for measuring the transmittance of glazing materials, errors in transmittance were obtained and were evaluated. The standard deviation of the transmittance measurements was less than 0.01 except at incidence angles of 70° where it was about 0.02.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Automobile paint colors; automobile windshield color; photometric tests; spectral reflectance; spectral transmittance; transmittance variation; vehicle glazing materials.

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